NORTHEASTERN FOREST EXPERIMENT STATION

Semiannual Report
Watershed Management Research

April 1, 1966 - September 30, 1966

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PROJECT 1601 - WATER YIELD IMPROVEMENT

General

This half-year marked the completion of two problem analyses selected for this project--Flood Flows from Spring Rainfall and Snowmelt, and Low Streamflow during Summer and Fall Months. It is interesting, however not surprising, to note that these two problems are almost identical in name to those chosen for study in Project 1602 at Parsons, West Virginia. This calls attention to the fact that the large problem in watershed management is getting equable distribution of inequitable water supplies. No doubt most watershed research projects would fit under this umbrella to a large extent.

A major undertaking was also completed this term by George Hart in his Ph.D. thesis: Streamflow Characteristics of Small Forested Watersheds in the White Mountains of New Hampshire. This study involved a comprehensive examination of many streamflow parameters and the calibration of our first three watersheds.

Unfortunately (for the project) George had no sooner completed this when he left to assume a teaching position at Utah State University. We are sorry to see George go but wish him well in his new adventure.

Construction of stream-gaging station #8 is well along and hopefully will be completed before winter. This station will be much like our newer styles--combination of a modified San-Dimas flume (4 foot wide) and a 120° - 1.75' high, V-notch weir in tandem.

Watershed #2 Treatment

Our clearcut watershed (much like Coweeta's watershed 17) was given a heavy dose of herbicide in June to eliminate all vegetative regrowth. Severe restrictions were placed on us in selecting a herbicide. Because of our cooperative study with Dartmouth College on mineral cycling of ecosystems, we did not want to introduce contamination in the watershed that would interfere with qualitative nutrient measurements of ions in streamflow, precipitation, soil, or vegetation. To be acceptable, a herbicide was needed that would not contaminate the watershed in the above respects, was nonspecific with regard to plants killed, was hopefully long-lasting (2 - 3 years), was easily applied from aircraft, and was nontoxic to macro- and micro-fauna, including humans.

Bromacil, a product of DuPont Company, was chosen because it best fulfilled the above requirements. It was further advantageous to use this because the Bromacil acts much like Fenuron; that is, it is taken up through the plant roots, translocated to the plant leaf, and disrupts the plant's ability to manufacture sugar, thus killing the plant.

We applied Bromacil from a helicopter at a rate of 25 lbs. per acre. This is greater than the recommended dosage; however, we felt it was necessary to apply the greater amount, realizing a fair amount would be lost in the mass of slash accumulated on the ground. The cost per acre (materials plus application) was a fantastic $140--probably too costly for practical use, however, it was not an exorbitant cost as a research tool, considering the difficult terrain and the "scorched earth" treatment desired.

The Bromacil has killed all growth on the forest floor and is rapidly eliminating regrowth of vigorous sprouts. First season results are encouraging.

Crude calculations of water yield from the treated watershed compared to the control are very exciting. From the first of January through the first week in September, the treated watershed yielded 13 area-inches of water greater than the control--and the year is not over!

Radiation Sampling--Early Results

One of the difficulties associated with the energy balance method of estimating evapotranspiration from watershed areas is an apparent spatial sampling problem in the measurement of net radiation. Apparently there has been no published work on the spatial variation or radiation components above forests. A study was begun in April 1966, to determine how great the spatial variation really is.

Economical radiometers were supported on towers at 12 points above several different cover types; hardwood (mainly gray birch with red maple, red oak, cherry), white pine reproduction, juniper opening, abandoned field, and ledge opening. The hardwood stand was selected for uniformity and height (about 30 - 35 feet). The towers were spaced about 50 feet apart in a 3 x 2 grid. The other sites were selected to give as wide a range of conditions as possible within a total area of about 6 acres. The white pine and juniper plots were within about 70 feet of each other and 300 feet from the gray birch area. Measurements are taken only on selected clear days and will be continued through all seasons of the year. All radiometers are read within about fifteen minutes, every half hour.

Table 1 shows results for 10:45 a.m. EST on July 8, 1966. These are quite typical of summer conditions. The measured radiation components show the largest scatter in the downward shortwave, which should be the same for all. This appears to be due to imperfect leveling interacting with the incident angle correction. Means of the measured downward components were used in the albedo and net radiation calculations. The field and hardwood albedos are much higher than the ledge and conifer; the surface temperatures are in the order: ledge, field, conifer hardwood; and the net radiation is in the order: conifer, hardwood, ledge, field. The albedo and the surface temperature are equally important in establishing the net radiation.

Comparison of all runs shows that the economical radiometer is not accurate enough to pick up consistent differences among the hardwood locations or among the juniper-pine locations, even though the juniper appears quite different from the pine visually.

It appears that significant local variation of net radiation does not occur within a given forest type, but does occur as the character of the cover changes. Radiation measurement over a fairly homogeneous watershed does not seem to present a sampling problem.

Effect of Slash on Snowmelt

In our clearcut watershed 2, all vegetation was left on the ground as slash. This slash is far from evenly distributed, and we are interested in the effects of different slash densities on snow melt rates. A simple visual rating scale for apparent slash bulk density was developed: 0 - no slash, 1 - light slash, 2 - moderate, 3 - heavy. Two yardsticks screwed together with a 6-inch overlap make simple snow stakes with which melt rates can be followed (assume constant density). Measurements with about 45 stakes last winter in the "ambient"slash indicated that snow melts fastest in moderate slash because its low albedo and high exposed surface increase energy absorption both from the sun and from the air. Heavy slash, however, impedes melt by providing an insulating layer; even though its albedo is high, the snow surface is shaded and most of the heat is transferred from the slash to the air.

This next winter we will measure snow melt rates in slash piled at a constant density through the pile. This should avoid the last year's problem with the "ambient" slash of increasing slash density at a point as the snow melts.

Table 1

Tower	Forest cover	Height above ground (feet)	R short up (ly/min)	R long up (ly/min)	Albedo	Surface temp. (°C)	R net (ly/min)
1	hardwood	40	.25	.62	.17	22	1.07
2	"	40	.25	.62	.17	22	1.07
3	"	40	.27	.62	.19	22	1.05
4	"	40	.27	.62	.19	22	1.05
5	"	40	.26	.61	.18	21	1.07
6	"	30	.25	.62	.17	22	1.07
7	juniper opening	20	.16	.65	.11	25	1.13
8	"	20	.18	.65	.13	25	1.11
9	white pine	20	.19	.65	.13	25	1.10
10	" "	20	.18	.65	.13	25	1.11
11	ledge opening	6	.18	.76	.13	37	1.00
12	abandoned field	10	.26	.70	.19	31	0.98

R short down range 1.39 - 1.46 mean 1.44

R long down range 0.49 - 0.51 mean 0.50

PROJECT 1602 - FLOODS AND WATER YIELD

Problem Analyses

Problem analyses for this project have finally been completed and approved. We have two: Flood Flows from Rainfall and from Combined Rainfall and Snowmelt; and Low Streamflow Especially during Summer and Autumn.

When it came to planning individual studies, we were unable to maintain the Problem distinction. Many studies will treat both the flood and low-flow problems.

Half-cut Watersheds

Lower Six and Upper Seven were cut and silvicided in 1963-64 and kept practically bare of vegetation since. Increased yields continue; over the last 29 months increases have totalled 28 inches (or 85 percent of expected discharge) on Lower Six and 31 inches (or 65 percent expected discharge) on Upper Seven.

The breakdown of forest floor is becoming more and more evident as exposure continues and annual increments of litter are not received to offset the loss. This has not yet resulted in appreciable overland flow and erosion, but we expect it is only a matter of time--and it probably won't take much longer. When we cut the other halves of these watersheds, we want to make a more detailed study of changes in the forest floor. For one thing, the leaf litter seems an effective barrier to evaporation from the soil. After its disappearance, direct evaporation may increase and offset part of the yield increases resulting from reduction of transpiration.

Energy Budget Study

A study of the differences in the energy budget of the cleared and forested halves of Watershed 6 is now under way. A slight delay occurred this spring when preliminary measurements indicated that the height of the climatic tower in the forested half was not adequate for wind profile measurements. Addition of two sections raised the total tower height to 100 feet and seems to have solved the problem.

To date most of the analyses of data has been confined to the radiation balance. Some interesting differences are showing up; the values below are for July 21, 1966 (0700-2100).

	Forest	Cleared
	gm. cal./cm^2/day	
solar down	674	674
solar up	126	82
net solar	548	592
thermal down	272	274
thermal up	363	410
net thermal	-91	-136
net allwave	457	456

For the day, 19 percent of the solar radiation was reflected from the forest. The cleared area, with dense piles of slash and exposed forest floor, reflected only 12 percent. A higher loss of thermal radiation from the warmer cleared area helps to equalize the net radiation for the two areas.

Although little work has as yet been done on computing values for the energy use components, it is readily apparent that one of the biggest differences will be in the sensible heat of the soil. While the forest soil shows only 1° or 2° F daily variations close to the surface, the cleared area shows 3° to 5° F daily variations at a depth of 15 inches and much larger differences near the surface.

Municipal Watershed

The City of Princeton, West Virginia is building an impoundment for municipal water supply as part of a small watershed project. We have been asked to undertake a study of dependable yield from the watershed. It promises to be both an opportunity and a challenge.

General

We increased our potential for accomplishment by converting our soil-moisture meter to americium-beryllium; and then we lost the man who was supposed to operate it. Chuck Troendle is on active duty with the Army reserve; we expect him back by Christmas.

--K. G. Reinhart
J. W. Hornbeck

PROJECT 1603 - WATERSHED CORRELATION AND SYNTHESIS

Ed Corbett arrived in June from the San Dimas Experimental Forest and immediately started catching up on the municipal watershed job. Foremost on the agenda was the repair of three leaking weir boxes, meetings with cooperators, and the collection of humus samples in New Jersey and Pennsylvania for the regional hardwood humus study.

Some municipal watershed managers have endeavored to produce cleaner, more neutral water by cutting forest vegetation approximately 20 feet back from stream banks and cleaning debris from the channel where accumulations of leaves can discolor streamflow and affect taste and pH. To evaluate the effect of this practice on water yield, riparian treatments were carried out last year on two experimental watersheds at Newark, N.J., and Baltimore, Md.

At Newark, trees in a strip 22 feet along both sides the stream channel were killed by injector treatment and the smaller vegetation deadened by a herbicide applied by mistblower. At Baltimore, the riparian zone vegetation (mostly hardwoods) was removed in a logging operation. This fall the stumps were pulled, the area scraped clean, and seeded to winter barley. During the growing season the barley will be processed to reduce the transpiring surface. Sediment samples will be taken.

We will evaluate the latter method as a non-chemical technique for controlling the regrowth of hardwood and herbaceous vegetation following riparian cleanup. Many municipalities do not allow the use of herbicides near streams.

Howard Lull busied himself by giving a paper on urbanization of forested watersheds, at the ASCE Hydraulic Division Meeting in Madison, Wisconsin attending a 3-days ARS Conference at Beltsville on watershed models, and spending a couple days with Richard Lee at the University of Connecticut. Working with Art Eschner (Syracuse), they came up with 21 streamflow records in the East with length of record from 35 to 55 years plus necessary precipitation and temperature data for a land use-streamflow trend analysis. With Bill Sopper (Penn State) completed an office report showing good correlation between flow intervals (Satterlund-Eschner type) and physiography and climate for 137 watersheds in the Northeast. With Don Mader (Univ. Massachusetts) prepared a report on accumulation and hydrology of white pine forest floor based on L, F, H, depth and weight measurements in 65 stands in Massachusetts, plus associated stand and topographic data and moisture contents.

We received a letter from H. C. Pereira (Rhodesia) that he was on his way to Ethiopia to receive from Emperor Selassie an Award for hydrological research--the award, 16,000 American dollars!

--Howard Lull
Ed Corbett

PROJECT 1604 - STREAM REGIMEN AND WATER YIELDS

Solar Radiation Relationships

The aerial tramway system used to investigate time and space variation of reflected short wave radiation above a red pine stand at Warrensburg, New York has been in operation for one year. Approximately 40,000 measurements have been taken and processed during this period. Computer programs have been prepared converting the voltage output of the Moll-Gorczynski solarimeter as it moves along the tramway to energy units, as well as pertinent statistical parameters.

Our confidence in the aerial tramway system has improved during the past six months. A total of five tramways at different levels and locations were used this past summer. As the height of the tramways above the canopy increased, the coefficient of variation decreased by a factor about 3.

Tramways were placed at ground level under the canopy to pick up information on the amount and spatial variation of solar radiation penetrating the entire depth of the canopy. From a very brief check of the computer output of this tramway it looks as if about 11 percent of the total incoming solar radiation at noontime reaches the forest floor under this 35 year old red pine plantation. Considerable work remains to be done with this under the canopy system to determine the proper sampling rate which will include the major sun spot frequencies.

Water Movement under Riparian vegetation

Measurments of the ground water table and soil moisture content in a sandy soil underlying a red pine plantation on a peninsula into Pack Lake at Warrensburg, New York were taken during the past six months.

Three liquid level recorders at various elevations produced a continuous record of the ground water table and lake level from April 23 to mid-November 1966. Recorders were checked and non-recording wells measured at frequent intervals during the period with a liquid level indicator. Soil moisture was sampled with a neutron probe at one-foot depths down to the water table at weekly intervals.

Although the data for the period are not completely analyzed, some pertinent points can be noted at this time.

1. Largest diurnal fluctuations during late June and early July.

2. Recording wells at the lower elevations had much greater diurnal fluctuations than those at high elevations.

3. Highest ground water elevations occurred in late May.

Recreation Induced Erosion

A cooperative investigation of trail erosion in the high peaks region of the Adirondacks was inaugurated this spring. The principal cooperator is Professor Ketchledge, Forest Ecologist of the College of Forestry. This three-year study will involve a survey of the erosion damage, sample plots to determine erosion rate, and control measures on approximately 40 mountain peaks.

The shallow organic soils, high precipitation, and increasing use of these areas by recreationists create highly unstable conditions. A reconnaissance survey and map of the erosion on 30 peaks was completed this summer. Location of sample plots will be determined this winter and initial measurements will be made next spring.

Physical Properties of Some Watershed Soils

A soil map has been made of a small watershed in the Alleghany Plateau on the basis of gross morphological differences. Large portions of the watersheds in the Northeast must be mapped as a complex, due to the extreme variability in soil properties over a short distance and lack of predominance of any one soil.

The reason for this large variability is that windfalls over the time since the soil parent material became forested have created a "mound and basin" type of microtopography. This topography is characterized by a succession of small mounds and dips with variations in elevations of from 1 to 3 feet between mound tops and depression floors. Often the only mineral soil under the depression surfaces is the top of the fragipan, consequently downward drainage is retarded.

These mounds and basins or depressions which are still being formed hold back or retard surface runoff and the depressions accumulate leaves, twigs, limbs, and sections of fallen trees. The result is a soil on top of the mound which is as much as 3 feet deep over the fragipan and appears to have good internal drainage down to about 6 inches above the fragipan. Four to ten feet away in the bottom of the depression all of the material above the fragipan may be peat, which in places is one foot thick. Other depression soils may consist of 3 to 6 inches of material that appears to be almost peat and then a very poorly drained mineral soil above the fragipan.

This summer a one-foot contour map of a 100 by 180 foot section of this topography was made. This map will be used to determine the water storage capacity of these depressions. Soil samples were collected and used for textural analysis and for determination of soil moisture suction curves near saturation. Organic matter as material lost on ignition will be determined, and attempts will be made to describe the saturated and unsaturated flow characteristics of the fragipan. The following table

illustrates some of the differences between soils on mound tops and in depressions:

Sample location	B.D. gms/cc	H^2O by wt. at .07 bars suction
Mound top	.81	61%
Basin	.23	375%

Miscellaneous

Project 1604 had its first operational season this past summer in the environmental field laboratory at the Pack Demonstration Forest, Warrensburg, N.Y. The field laboratory originally designed to investigate tree response to various levels of fertilization, has been adapted to study several systems of physical activity of the environment as well.

The installation is located in a two-acre, 35-year-old Red Pine plantation on a deep coarse sand outwash flat plain. Instrumentation in the area includes 36 sideless tension lysimeters under 0.1 atmos. constant tension, located at soil depths of 6, 24, and 60 inches depth. Soil moisture determinations are facilitated by a network of 24 twelve-foot neutron access tubes. Both soil moisture, depth probes, and density probes are in use. An overland, gravity-feed irrigation system provides an even distribution of water to designated portions of the area at the rate of 0.06 inch per hour. A field climatic laboratory is in operation in the area. Various aspects of the radiation balance as well as air and soil temperature are recorded with standard strip chart recorders.

PROJECT 1605 - FOREST RESTORATION OF STRIP MINED LANDS

General

Change still dominates the mood at Berea. The shift in stations was soon followed by a shift in personnel. Robert F. May, our able leader, moved on to Washington and was replaced by Grant Davis. Grant moved down from Kingston, Pennsylvania where he had been engaged in research on revegetation of coal mine spoils.

Just about the time we received word that our vacant position of Civil Engineer had been filled, Dave Striffler, our hydrologist, resigned to teach at Colorado State. George P. Williams, Jr., our new engineer has just arrived from New Mexico with his wife and 3 children and a 60-foot mobile home.

After a month's leave of absence, Frank B. McKinney, Forest Worker, has returned to our staff.

Grant Davis attended the annual field tour and meeting of the Ohio Reclamation Board of Review and explained the research program of the Berea project to the Board and guests.

Bill Berg and Willis Vogel presented papers at the meeting of the American Society of Agronomy, on August 25th, in Stillwater, Oklahoma.

--Grant Davis

Spoil Bank Chemistry

On spoils derived from strip mining for bituminous coal in the Appalachian region, the addition of N and P are required on many spoils for fast establishment ground cover. Plant available phosphate varies considerably among spoils. The Bray test for available P correlates well with plant establishment and initial growth on these spoils. Soil tests using strong acid extractants could not be correlated with plant growth. Spoils usually contain a considerable percentage of coarse fragments up to 1/2 inch diameter. Including coarse fragments necessitated using 20 gram samples in place of the usual 1 or 2 grams.

Nitrogen is deficient on spoils when quick vegetative cover is desired. Among spoils discrete differences are apparent in plant available N, these can result in as much as 13-fold differences in dry weight of vegetation produced. No spoils were found on which K limited plant establishment or initial growth.

--William A. Berg

Strip-Mine Survey of Eastern Kentucky

Early this summer we completed the area determination for the strip-mine survey of eastern Kentucky. Final figures showed 56,582 acres disturbed by mining and 3,916 acres disturbed by coal haul roads. Publications summarizing this data have been prepared and should be in print soon.

We have also completed the data collection for the field survey to determine characteristics of the mine disturbance. The data is being tabulated and will be summarized this winter.

At the same time we were completing our survey, the Tennessee Valley Authority finished one in western Kentucky. While different systems were used, we can and will cooperate in a joint publication describing the extent and characteristics of stripping in eastern and western Kentucky.

--William T. Plass

The Effects of Leveling on Plant Establishment and Growth

Final plans are being made for two studies to extend our knowledge of the effects of spoil bank leveling on plant establishment and growth. The primary objective of one study is to compare compaction after leveling with rubber tired and tracked leveling equipment. We are including scarification treatments to break up anticipated compaction. The other study will compare the effects of three degrees of grading--none, strike-off and complete.

Several other aspects not previously investigated will be included. Nuclear sensing will be used to determine soil moisture at several depths during periods of deficient and abundant rainfall. We will also evaluate a method for quantitatively measuring erosion losses and the effect of vegetation on these losses.

The study area will be graded this fall and planted and seeded next spring. By next fall preliminary data should be in.

--William T. Plass

Herbaceous Vegetation

Results of our field and greenhouse evaluations of herbaceous species show that weeping lovegrass has consistently given faster cover on acid spoil than any other herbaceous species we have tried. When fertilized with nitrogen, and phosphorus, where needed, this grass has made rapid growth and excellent cover on spoils with pH's around 4.0. Ground cover

of 90 to 100% has been obtained on plots within 100 days after seeding. In greenhouse trials, growth and yield of weeping lovegrass were not affected in spoils relatively high in water soluble manganese (18-25 ppm). Switchgrass, too, is about as tolerant of acidity and manganese as weeping lovegrass, but takes at least two growing seasons to make satisfactory cover.

Seeded in mixtures with other grasses and legumes, and fertilized with N and P, weeping lovegrass made up 90 percent or more of the cover composition near the end of the first growing season. Where nitrogen was not added composition of legumes equaled or exceeded the weeping lovegrass, but total cover was much less than on N fertilized plots.

Because of the low nitrogen status of spoil, legumes would appear to be more promising than grasses for revegetating strip mine spoil. But legumes are not as acid tolerant as some of the grasses. For example, when seeded in the greenhouse Sericea and Korean lespedeza failed to grow beyond the seedling stage in a spoil of pH 4.1 that gave good growth of weeping lovegrass. When compared with Korean lespedeza, Kobe variety of common lespedeza and birdsfoot trefoil were more tolerant of manganese toxicity than Korean lespedeza.

Other exploratory studies in the greenhouse showed that Sericea lespedeza did not nodulate in spoils below pH 4.5. Furthermore, nodules appeared to be of little effect in supplying nitrogen to Sericea lespedeza plants within 60 days after seedling emergence. In a spoil of pH 5.2 Sericea at 60 days made very little growth with added phosphorus but responded well to nitrogen. In comparison, Korean lespedeza made good growth with added phosphorus only, indicating nodules were supplying nitrogen.

Considering this information from a management viewpoint, it would appear that legumes would be better than grasses for herbaceous cover on most spoils because nitrogen fertilization would not be required. But, if legumes will not nodulate or grow well in acid spoil below pH 4.5 the alternative would be to use a tolerant grass with nitrogen and, where needed, light phosphorus fertilization.

Assuming that herbaceous cover is necessary on spoil banks only during tree establishment, a good initial stand of grass would not necessarily need to be maintained with fertilizer. Hopefully, tree cover would be established before the grass cover diminished.

--Willis G. Vogel

PROJECT 1606 - MANAGEMENT OF STORM RUNOFF

The past six months have been spent in the field studying water movement both by plots and soil cores.

In the past (1964 and 1965) our plot studies have shown that much flow by-passed our water-collection systems if the root systems extended beyond the cutoff area.

In our fall 1964 report we noted from our field observations that:

> "Where the surface horizons of our forest are so intrinsically permeable and are characterized by seemingly interconnected roots and root channels in all stages of decay, there seems to be little chance that all the water sprinkled on the uphill portion of the long, narrow plot can flow down the plot to the open face. Observations showed that some flow was by-passing (in a lateral direction) the face and the wetted plot border flowing instead through root channels from beyond the wetted zone. Substantiating the observation that loss occurred through lateral interconnected channels was the fact that tensiometers placed at the edge of the plot and beyond in the unwetted soil showed no buildup of a saturated zone in the lateral direction.
>
> "To see if this bypass loss increased with time and wetting, we repeated the same run (intensity and time similar) for two weeks. There was no apparent difference in total outflow quantity as antecedent moisture builtup in the plot. From observation the greatest volume of bypass flow was coming from the permeable soil horizon overlying the impeding zone and was predominate from root holes and other natural channels in the soil." ...

Our fall 1965 report then detailed the manner in which we opened the sides of this long plot to learn where bypass flow was coming from. We found that along the 125-foot plot that

> "...the observed line of saturation was an undulating line above a fine-textured impeding layer at about 32 inches depth. No flow occurred from the sides in the trench until after the fourth simulated storm. Here again flow came through root holes, cracks, decayed root channels, and earthworm holes. It was obvious that these openings were interconnected to some extent, and that many were open to the soil surface, for this outflow came from that travelling laterally through an unwetted (on surface) buffer strip before flowing into the open trench. As in seepage from the downslope face we found no evidence of a general zone of saturation at the upper level from which the seepage occurred; this further indicated to us that flow was coming primarily from interconnected macro-pores and openings..."

In late spring of this year (1966), we established a plot in a Keene silt loam soil to study flow in a wetted, fine-textured soil well permeated with root holes and old channels. The face of the plot with the seepage collection system was installed immediately below an old stump. We felt this would have some influence on flow. The trough was placed 20 inches below the soil surface in a somewhat impervious clay loam. However, numerous roots were found below this cutoff.

Sprinkler runs were made intermittently on this plot for about six weeks. However, no appreciable seepage occured from this plot and we are convinced that much of the water moving through the plot bypassed the collection system--quite probably through channels created by the decayed stump and others. We now plan to lower the cutoff and collection system to about 42 inches deep to see if there is any pick-up in flow from the same-sized storms made earlier.

None of this, of course, is new information to forest hydrologists involved in study of subsurface stormflow. But is useful in that for all plots the rainfall was controlled, the antecedent soil moisture potentials were measured, and the storms were repeated with similar results. And it did tend to confirm earlier findings, i.e., that we were not dealing with flow from a more or less uniformly saturated soil mass. This latter case has been studied in detail by drainage scientists and is largely a function of the hydraulic conductivity of the soil.

In the case of forest soil, however, saturated-type flow is extremely complicated for it is more nearly like that studied in hydraulics with compound, branching, converging, and diverging pipe systems. It is further complicated by the fact that effluent or influent flow may take place anywhere in the system (that is, the system is not closed) and the initial source of supply to the system is difficult to ascertain.

Our latest plot (45' x 60') is on a Wellston loam soil with cutoff and trough approximately 48 inches below the soil surface. Our initial wetting runs have given us high peak rates of seepage (120 csm) for 90-minute low intensity storms. As wetting continues and a continuum of moisture builds up in the interconnected channels, we expect high rates of storm runoff and prolonged recession periods. For this reason we have equipped the trough outlet with an HS-flume, 0.6-foot deep. In addition to artificial storms, the flume will also enable us to record seepage from winter storms occurring on the hillside. The natural slope above the flume extends for about 240 feet to the ridge. The soils are Hartsell and Dekalb sandy loam, quite coarse textured and readily permeable to water movement. Although the plot is equipped with a 45-foot wide cutoff, we are wetting only about a 25-foot wide strip. This allows approximately 10 feet of unwetted buffer strip and we hope this will minimize loss of water in a lateral direction. Where the channels are completely sealed from the atmosphere and not wetted directly, there is a resistance to wetting. We found in the past that flow bypassed buffer strips of 4 to 5 feet wide.

Also in the past we have spent much effort to little avail to show seepage from cracks and channels in open soil cuts and from raw streambanks. However, Aubertin this past summer has worked with fluoresceine dye and ultra-violet lighting and has been able to show seepage fed by both ponded water and sprinkled water from cracks and holes in an open face. These photos have descriptive value in that we have heretofore had difficulty convincing some of our drainage colleagues that deep flow does occur before the entire soil mass is saturated.

Based on what we have known previously and what we have seen and are still finding, we must learn much more of the flow medium, the soil. However, it is not enough to study the soil mass--for the soil openings are the predominate routes of saturated type stormflow. We must understand the geometry of these (essentially) hydraulic channels as "water supply and feeder routes."

Gerald Aubertin is currently starti g a review of literature study into growth, development, and decay of woody plant roots. Several major laboratory and field studies into size, distribution, and extent of rooting and channelization will evolve from this.

At the same time, we have a cooperative-aid study with the Ohio State University on methods of obtaining and examining soil samples containing large quantities of void spaces and roots. At present this study is concerned with making thin, microscopic slides to study voids and annular spaces adjacent to roots and also to study the compaction and eventual pipe-wall effect of pressures exerted by the dynamic growing root. They hope to come up with a technique for solidifying and slicing large cross-sectional soil samples without disturbing large voids and large roots. A wholesale sampling of roots in three dimensions will give us a more realistic idea of the geometry of voids, water-conducting roots, and channels in forest soil.

--R. Z. Whipkey

<u>Hydraulic Conductivity Research</u>

A large amount of hydraulic conductivity field and "lab" data has been obtained using the methods and procedures indicated in the last semiannual report. While these data are not fully analyzed, the indications are that there is a close relationship between the presence of old root channels and overall conductivity. The nature of the data strongly suggests that with our forested soils, the overall conductivity is made up of two parts. The first is the hydraulic conductivity through the soil matrix itself and the second is essentially inter-mass flow through old root channels, cracks, and macro-organism pathways. In our studies the matrix conductivity is often completely masked by inner-mass flow which may be several hundred times more rapid. Due to the nonuniform distribution of the channels, cracks, and pathways within the soil profile and the unknown

contribution of a given channel, crack or pathway within a sample, interpretation of the data becomes quite sticky. (Note: Under certain conditions, such as a channel sealed off from the atmosphere, the channel may act as a barrier to water movement since the water will not enter the closed channel until the pressure within the water surrounding the channel exceeds the pressure within the channel.) While the results from these methods are superior to those obtained from methods using smaller size samples, they still do not give us all the information we need. Consequently, we are still looking for a method or methods which will take into account the geometry and individual contribution of the old root channels, cracks and macro-organism pathways.

In an attempt to qualitatively show the contribution of old root channels, cracks and macro-organism pathways to the overall hydraulic conductivity, pits were dug exposing the upslope face of the soil profile. The soil above the pit was wet either by sprinkling or ponding water containing fluoresceine dye; outflow from the pit face was then recorded and photographed. We were interested to note that from a sprinkling of 1-inch per hour on a silty clay loam, seepage first occured from the heavy clay zone 48 inches below the soil surface only 15 minutes after wetting started. The deeper channels began flowing first with subsequent shallower and shallower root channels beginning to flow with increased length of wetting time. After approximately two hours, flow was just beginning from a root channel at 17 inches below the soil surface. There was no visual sign that the soil mass itself was wetting up. All the flow occurred from old root channels.

In another application of sprinkled water to the silty clay loam, outflow began from a 1/4 -inch diameter old root channel at a depth of 23 inches beginning at approximately 9 minutes after starting to wet the soil. This particular root channel yielded an initial measured outflow volume of 1127 ml/min. In all runs on the silty clay loam, there was at least one and often more old root channels that flowed pipe or faucet like.

The use of ponded water on the same silty clay loam produced similar results. In addition to flow from the immediate plot, we also observed flow coming from channels in another pit almost 30 feet obliquely down slope from the ponded water source. This was first observed 45 minutes after water was applied. While it is highly improbable that such a ponded water condition ever exists naturally, the results point up the high degree of interconnection between channels in these undisturbed soils.

Similar runs on a sandy loam produced similar but less pronounced results. Seepage was not restricted to old root channels and the sandy layer at approximately 46 inches in depth overlying a heavier sandy clay zone wet up rather uniformly and began to seep within 35 to 45 minutes after wetting the soil. At one location a chipmunk nest filled with acorns was exposed in the pit face. This cavity provided a pathway for substantial outflow. The most noticeable difference between the sandy and silty

soils was that in the sandy soils the soil itself appeared to wet up and the initial time of outflow from the root channels did not appear to be related to the depth of the channel. Also the volume of outflow from individual root channels was usually considerably less in the sandy soil than in the silty clay soil.

Our work on pore size distribution came to a virtual standstill this summer due to the press of field work and some difficulty in obtaining a suitable permeable material. However, we expect to report on the results in the next report.

Currently we are embarking on an extensive-comprehensive literature review on the growth, development, and decay of woody plant roots. We have several specific studies in mind but find that due to the complexity of the subject and the wide dispersion of information, a comprehensive literature review is in order. We plan on publishing this review as soon as possible for the benefit of our co-workers who are faced with the same problems. We would appreciate hearing from any of our colleagues who are actively engaged in, or are interested in forest tree root research.

--G. M. Aubertin

PUBLICATIONS

Plant-Toxic Chemicals in Acid Spoils. William A. Berg. Proc. Coal Mine Spoil Reclamation Symposium, Penn State, 1965. pp. 91-96.

The Cooperative Research Program in Pennsylvania. Grant Davis. Proc. Coal Mine Spoil Reclamation Symposium, Penn State, 1965. pp. 55-61.

Research in Strip-Mine Reclamation. E. A. Johnson. Symposium on Strip-Mine Reclamation, Lexington, Ky. 1965. p. 11.

How Harvesting Forest Products Affects Water Yield in Appalachia. Howard W. Lull and William E. Sopper. Proc. Soc. Amer. Foresters 1965: 108-112.

Factors that Influence Streamflow in the Northeast. Howard W. Lull and William E. Sopper. Water Resources Research 2: 371-379, 1966.

Overburden and Bank Acidity...Eastern Kentucky Strip Mines. Robert F. May and William A. Berg. Coal Age 71: 74-75, 1966.

A Method for Estimating Streamflow Loss by Evapotranspiration from the Riparian Zone. Irvin C. Reigner. Forest Sci. 12: 130-139. 1966.

The Forest Restoration of Strip-Mined Areas. W. D. Striffler and Robert F. May. Soc. Amer. Foresters Proc. 1965: 106-108.

Road Erosion and Spoil Bank Stability. Weldon K. Weigle. Proc. Coal Mine Spoil Reclamation Symposium, Penn State, 1965: 82-85.

Spoil Bank Stability in Eastern Kentucky. Weldon K. Weigle. Mining Congress Journal 52: 67-68, 73, 1966.

Erosion from Abandoned Coal Haul Roads. Weldon K. Weigle. Jour. Soil and Water Conserv. 21: 98. 1966.

Manuscripts Submitted:

Fertility Requirements for Establishing Herbaceous Cover on Acid Strip Mine Spoils. William A. Berg and Willis G. Vogel.

New Radiation Instruments. C. A. Federer.

New Stream-Gaging Instruments. George Hart.

Water--Sources for the City. Howard W. Lull.

Radiation Measurements by Various Instruments in Open and Forest. Howard W. Lull and Irvin C. Reigner.

Increasing Water Yield in the Northeast by Management of Forested Watersheds. Howard W. Lull and Kenneth G. Reinhart.

Hydrological Effects of Urbanization of Forested Watersheds in the Northeast. Howard W. Lull and William E. Sopper.

Watershed Aspects of Stabilization and Restoration of Strip-Mined Areas. Robert F. May and William D. Striffler.

Evidence of Overland Flow on Forested Watersheds. Robert S. Pierce

Selecting Grasses and Legumes for Cover on Acid Strip-Mine Spoils. Willis G. Vogel and William A. Berg.